TMI Revisited Notes

This presentation addresses the Three Mile Island nuclear power plant accident

Slide 3 – TMI reactor plant schematic

- slide shows major structures to be reactor containment building, auxiliary building, turbine building, and dual cooling towers
- entire primary coolant system, including steam generators, enclosed by reactor containment building
- emergency core cooling system (ECCS) core flood tanks located in reactor containment building
- ECCS high pressure injection pumps, located in auxiliary building, pumped water from borated water storage tank into reactor coolant inlet piping
- steam cycle power plant located in turbine building

Slides 4 – reactor coolant system (RCS) graphic

- system consisted of two cooling loops with steam generator and 2 reactor coolant pumps per cooling loop
- pressurizer used to control RCS pressure

Slide 5 – once-through steam generator (SG) graphic

- high-pressure reactor coolant enters top of SG, flows down through tubes connected to upper and lower tube sheets, and exits at bottom of SG
- low-pressure main feedwater and auxiliary feedwater flow through peripheral downcomer to top of lower tube sheet, then up and around tubes to remove heat from reactor coolant flowing in opposite direction in tubes
- generated steam exits through nozzles in upper part of SG

Slide 6 – pressurizer graphic

- controls reactor coolant system pressure by maintaining high-temperature, high-pressure steam bubble in upper portion of vessel
- steam bubble pressure controlled by use of heater bundle in water section of vessel and spray nozzle in steam section of vessel
- pressure relief and safety valves located at top of vessel

Slide 8 – TMI condensate & feedwater and emergency feedwater systems

- schematic shows plant’s condensate and feedwater system that provides cooling water to secondary side of steam generators
- blockage in condensate polisher unit (water treatment unit circled in red at lower right) was accident initiating event that reduced water flow to main feedwater (MFW) pumps

- when MFW pumps (circled in red at lower left) tripped offline due to low suction pressure, normal feedwater flow to secondary side of SGs was lost
- emergency feedwater (EFW) pumps automatically actuated, but normally-open EFW block valves (circled in red at upper left) were closed (due to human error when scheduled maintenance performed on EFW system 2 days before accident), preventing EFW flow to SGs

Slide 10 – reactor coolant system prior to accident graphic

- graphic illustrates status of reactor coolant system prior to accident initiation

Slide 13 – TMI accident sequence (cont.)

- because power-operated relief valve didn't re-close, steam bubble in pressurizer began rapid reduction in volume; control board light indicated PORV was closed
- high pressure injection throttled in accordance with loss-of-coolant accident (LOCA) procedure to prevent potentially over-pressurizing reactor coolant system if pressurizer went "solid"
- loss of coolant through stuck-open PORV ultimately resulted in reactor coolant system pressure falling below boiling point of water at reactor core temperature, thereby creating steam bubbles in reactor core

Slide 15 – reactor coolant system 8 minutes into accident graphic

- reactor coolant pressure control lost (pressurizer steam bubble lost)
- total loss of reactor coolant heat removal (SGs boiled dry)
- control room operators now in uncharted territory – accident conditions outside domain of LOCA procedures

Slide 17 – reactor coolant system 1 hour into accident graphic

- because reactor operators trained in strict adherence to prescriptive operating procedures, overly focused on pressurizer water level instead of on decreasing reactor coolant pressure early in accident
  - led to subsequent ambiguous control room indications and reactor system conditions that complicated task of mitigating accident while still adhering to operating procedures
  - control room alarm boards "lit up like a Christmas tree"
  - computer alarm log was printing one line every 4 seconds
- feedwater flow restored to SGs when EFW block valves opened
- failure of PORV to re-close resulted in continuing loss of reactor coolant water, directed to containment building quench tank
- when quench tank became full, tank rupture disk burst and water then flowed to containment building sump

Slide 19 – reactor coolant system 1.5 hours into accident graphic

- Loop B reactor coolant pumps shut down to prevent cavitation damage
- reduced circulation of reactor coolant flow through reactor core caused steam bubbles to collect in reactor vessel head – phenomenon not previously postulated for LOCA

Slide 21 – reactor coolant system 2 hours into accident graphic

- Loop A reactor coolant pumps shut down to prevent cavitation damage, resulting in loss of forced circulation cooling of reactor core
- reduced heat removal from top of fuel elements now being exposed to steam rather than reactor coolant

Slide 23 – reactor coolant system 2.8 hours into accident graphic

- stuck-open PORV discovered and block valve closed, terminating loss of reactor coolant
- for next 5 hours, numerous attempts to establish heat removal trough SGs
- attempts at establishing forced circulation or natural circulation through reactor core unsuccessful due to steam blockage of reactor vessel outlet piping
- major fuel damage occurs from overheating (indicated by containment building radiation monitoring instrumentation)

Slide 24 – reactor coolant system 3 hours into accident graphic

- reactor core cooling further reduced when Loop B SG isolated
- more of fuel exposed to steam

Slide 26 – reactor core end-state configuration graphic

- slide illustrates final reactor core configuration at termination of TMI Unit 2 accident
- fission product decay heat continued to boil off water in reactor core region uncovering more of fuel until top half of core melted at about 4 hours into accident

Slide 27 – reactor coolant system 16 hours after accident initiation graphic

- re-establishment of Loop A reactor coolant flow, restoring forced reactor core cooling, terminated accident

Slide 29 – TMI accident radiation release pathways graphic

- slide illustrates accident radiation release pathways
- only inconsequential quantities of noble gases krypton and xenon released from plant stack to environment as shown in graphic
- auxiliary building heavily contaminated with radioactive reactor coolant

- reactor coolant from stuck open PORV directed to quench tank in reactor containment building
- after quench tank rupture disk burst, water collected in containment building sump
- water in containment building sump automatically pumped to radioactive waste storage tanks in auxiliary building because containment building isolation not actuated (building overpressure actuation setpoint not achieved for PORV LOCA)
- blown rupture disk on radioactive waste storage tanks allowed radioactive reactor coolant water to collect on auxiliary building floor

- no radioactive liquid effluent released from auxiliary building to environment

Slide 36 – TMI-2 control room photo

- alarm boards are in upper portions of control room panels as seen in this photograph, which was likely taken during plant startup testing since numerous alarms are illuminated

Slide 38 – TMI-2 unexpected source range neutron monitor (SRM) signal

- slide shows unexpected readings from SRM in first 4 hours of accident
- readings reflected changes in state of reactor coolant in reactor pressure vessel downcomer

Slide 39 – TMI reactor pressure vessel graphic

- slide shows path of reactor coolant flow through pressure vessel downcomer and reactor core
- changes in mixture of water and saturated steam in downcomer affected neutron flux detected by SRM
  - more attenuation from decreased steam content resulted in decreased count rate
  - less attenuation from increased steam content resulted in increased count rate

Slide 50 – TMI post-accident photo

- TMI nuclear power plant didn’t look any different following accident at Unit 2 because physical consequences of accident totally confined within reactor containment building and auxiliary building